



# Failure analysis of handhole flange cracking

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## ABSTRACT

A failure analysis was performed on a cracked handhole flange. Through the analysis of the macro morphology and microstructure of the crack, the metallographic analysis, the mechanical properties test, the chemical compositions analysis of flange material, and the energy spectrum test, the main reason for the cracking can be described as liquation crack, and the failure was aggravated by the sensitization of flange materials. Conclusions and corresponding preventive measures were put forward.

## 1. Introduction

With the rapid development of industry, plenty of equipments have adopted the welding structure. Cracks in the welding process are dangerous to the safety operation of the equipment. The low-melting point phase of austenite grain boundary near the weld metal melts under high temperature, and micro crack defined as liquation crack generates along the austenite grain boundary caused by the tensile stress in the process of solidification, which belongs to welding hot crack. Liquation crack could generate at the hollow zone of welding-fusion line and interlayer overheat zone of multi-layer welding. It is the source of the cold crack, reheat crack, brittle fracture and fatigue fracture [1].

When the low-melting point substances gather at the grain boundary, the metal compounds break down and hardly have enough time to spread because of the rapid process of heat welding, and certain metal elements will gather at the boundary and even become crystal. Then, the liquation crack will generate along the austenite grain boundary caused by the tensile stress. Moreover, in the unbalanced heat treatment conditions, the high local eutectic composition will give rise to the local crystals liquefy caused by the intermetallic compound decomposition and diffusion, which will also cause the liquation crack. The reasons of liquation crack can be drawn:

- (1) The gathering, eliquation and eutectic of some low-melting point elements, like P, S, B, etc.
- (2) The existence of the nonmetallic inclusions, like  $Al_2O_3$ ,  $CaO$ ,  $SiO_2$ , etc.
- (3) The stress state of welded joint [2].

Intergranular corrosion is one of local corrosion damage of the metal grain boundary in certain corrosive environments. It starts to form in the outer surface and extends to inside surface, which will reduce the binding force of grains, and the material strength will completely disappear nearly. The primary cause is the inhomogeneity of electrochemical corrosion in grains and grain boundary areas, which is caused in the process of the melting, welding and heat treatment. The most widely theory of intergranular corrosion mechanism model is the poor chromium theory [3], which has been confirmed already.

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Fig. 1. The appearance of the handhole flange.

In the heat preservation or slow cooling treatment process in the range of 450 °C~900 °C, the austenitic stainless steel will present an intergranular corrosion sensitivity in the corrosive medium after solution treatment, which is called material sensitization, and the temperature range is called sensitization temperature range [3]. In this process, C is inclined to combine with Cr to form the complex compound  $\text{Cr}_{23}\text{C}_6$ , and precipitate at the grain boundary from the supersaturated austenite [4]. The mean mass fraction of Cr in  $\text{Cr}_{23}\text{C}_6$  is much higher in grain, therefore, the precipitation of the  $\text{Cr}_{23}\text{C}_6$  will cause the Cr depletion in the grain boundary area. In terms of the diffusion rate, C is much faster than Cr in austenitic, and the consumption of Cr can not be supplemented. The result is the poor chromium area will form around the grain boundary area, and the mass fraction of Cr is lower than the minimum value (0.12) to form passive film on the steel surface. The grain and the boundary area will compose a micro battery with large cathode and small anode, and the corrosion is accelerated [3].

## 2. Description of the handhole flange failure

The handhole flange of a heating furnace radiant chamber cracked in May 2016. The failure of the flange affected the normal operation, and the failure analysis was essential. As shown in Fig. 1, the flange is classified as welding neck flange.

According to the information examined, the flange was produced according to the standards of ASME II A2010ED + SA182M and HG/T 20615-2009A, and the material is SA182-F347H steel. The specification is WN350-300RF S = 11.13. The flange operated at 625 °C with atmosphere rich of hydrogen oxygen, nitrogen, methane, ethane, and etc.

## 3. Fracture surface detection

As shown in Fig. 2, the penetrating circular cracks are located in the flange side heat affected zone and the transition area of the straight side and the hypotenuse. The inside and outside of the crack part are covered with black layer, and no plastic deformation occurred.

Specimen removed from flange along the crack was prepared for the follow-up experiments. The fracture morphology is shown in

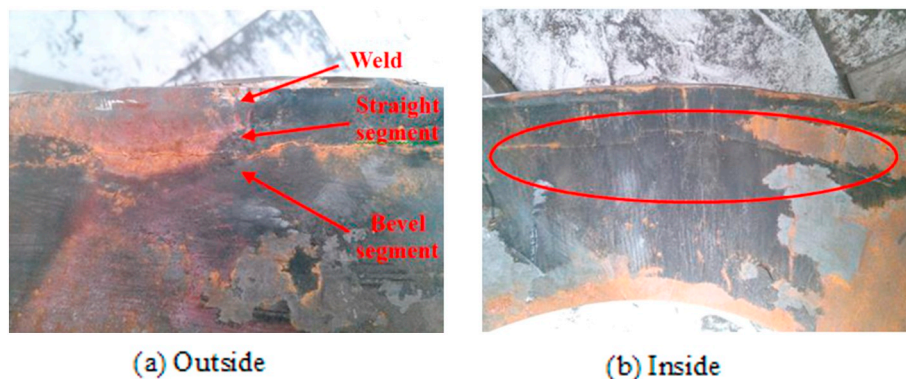


Fig. 2. The circular crack morphology.

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